LUMINESCENT SILHOUETTING IN STOMIATOID FISHES[1]

By William T. O'Day[2]

Abstract: The luminescence which silhouettes three stomiatoid fishes—*Stomias atriventer, Idiacanthus antrostomus,* and *Chauliodus macouni*—has been seen repeatedly in adrenalin-stimulated specimens. It has been photographed in *S. atriventer*. The silhouetting luminescence derives from minute, unpigmented organs, found along the dorsal and ventral margins of these fishes and on all the fins. These luminous organs are composed of innervated aggregations of secretory cells.

Stomiatoid fishes inhabit the depths of the oceanic midwaters. Among their remarkable adaptations is their multiplicity of luminescent organs (Brauer, 1908; Gibbs, 1964, 1969; Morrow, 1964a, 1964b, 1964c; Morrow and Gibbs, 1964; Goodyear and Gibbs, 1969). I report new observations of bioluminescence in three species of stomiatoid fishes–*Stomias atriventer* Garman, 1889, *Idiacanthus antrostomus* Gilbert, 1890, and *Chauliodus macouni* Bean, 1890 (Families Stomiatidae, Idiacanthidae, and Chauliodontidae, respectively, all belonging to the Suborder Stomiatoidei, Order Salmoniformes). The classification referred to is the one proposed by Greenwood et al. (1966). These fishes can be outlined by bioluminescence from numerous organs of the simple, unpigmented type. The organs are composed of innervated masses of secretory cells which emit light after stimulation with adrenalin.

Materials and Methods

Fishes were collected in deep waters off southern California by the R/V *Velero IV* of the University of Southern California. Some were also obtained during one cruise of the R/V *Alpha Helix* of the Scripps Institution of Oceanography. Observations of luminescence were made in the darkroom on board ship. Tactile stimulation was occasionally effective in eliciting luminescence from these three species but my usual method of stimulation was to add a small quantity of adrenalin solution (roughly 10 ml of 0.01% to 0.1% adrenalin in seawater) to 1-4 liters of cooled seawater in a tank containing the specimen. Sometimes, however, I applied a few drops of adrenalin solution directly on the skin of the fish. I also injected *Stomias* intraperitoneally and intramus-

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cularly with adrenalin (about ¼ to ½ ml of 0.1% solution of adrenalin in phosphate buffer, 0.15 M, pH 7.5), while subsequently injecting controls with an equivalent volume of buffer alone.

Photographs of bioluminescence were made by placing the glowing fish directly on a large sheet of Kodak Plus-X Pan film, which had been sealed inside a plastic bag, for about 30 to 60 seconds.

SPECIMENS

Stomias atriventer

Three specimens, 149 to 228 mm standard length (SL), were used for most of the histology. Bioluminescence was observed in 23 specimens, 137 to 250 mm SL.

Idiacanthus antrostomus

One specimen, 95 mm SL, was used for histology. Bioluminescence was observed in eight specimens, 258 to 335 mm SL.

Chauliodus macouni

Three specimens, 71 to 230 mm SL, were stimulated with adrenalin without eliciting a luminous response and subsequently used for histology. These specimens, however, were nearly dead. Another specimen, 115 mm SL, did luminesce when stimulated with adrenalin.

APPEARANCE OF THE LUMINOUS ORGANS

Each of these fishes has several kinds of luminescent organs. Large body photophores form ventral and ventrolateral rows. Prominent light organs lie near the eye and on close inspection very small photophores appear in various areas all over the body. In *Stomias* and *Idiacanthus* a luminous barbel trails from the lower jaw. All of these luminescent organs are easily visible in preserved specimens. However, an additional kind of luminescent organ is inconspicuous in preserved specimens of *Stomias* and *Chauliodus,* although it is quite evident in undamaged living specimens. Brauer (1908) referred to it as the simple, unpigmented type since no reflector or pigment sheath is present. In both *Stomias* and *Chauliodus* luminous organs of this type are embedded in a gelatinous sheath that envelops the fish. Spherical to ovoid bodies of simple, unpigmented luminous tissue form an irregular row along the dorsal and ventral margins of *Stomias* (Fig. 1a) and they extend along the rays of all the fins (Fig. 1b). in *Chauliodus* spherical bodies of luminous tissue are distributed along the dorsal and ventral margins of the fish and on all the fins. By contrast, *Idiacanthus* lacks the gelatinous sheath and instead has a row of chevron-shaped patches of luminous tissue along its dorsal margin and rows of small patches of luminous tissue along its ventral surface, with similar tissue along the rays of all the fins. In all three species this luminous tissue appears bright pink in life.

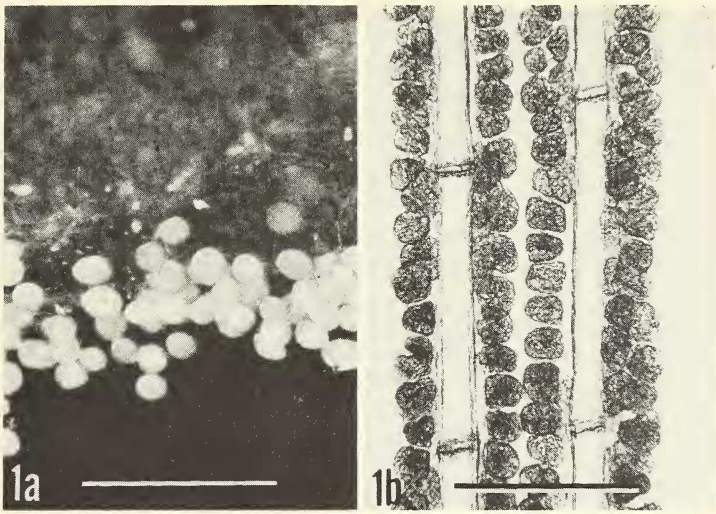


FIGURE 1a. Minute balls of naked luminous tissue along the ventral margin of the body in a specimen of *Stomias atriventer* 149 mm SL. Photographed under a dissecting microscope. The scale equals one mm.

FIGURE 1b. Luminous tissue along two branches of a ray from the anal fin of the same specimen. Photographed under a compound microscope with transmitted light. The scale equals 0.5 mm.

OBSERVATIONS OF LUMINESCENCE

There have been no published observations of luminescence of this tissue in either *Stomias* or *Idiacanthus*. However, P. J. Herring of the National Institute of Oceanography in England has made some related observations (personal communication). There is a single report of luminescence from the spherical bodies of tissue on *Chauliodus sloani* by Skowron (1928), who saw them emitting a bluish light. He also saw blue luminescence from the large body photophores of this fish. It remained alive in a tank for 45 minutes, during which a steady pale bluish luminescence issued from the ventral region when it remained undisturbed. Touched with a glass rod, the fish emitted pulses of luminescence which lit up the contours of its body.

The unpigmented luminous bodies found on *Stomias, Idiacanthus,* and *Chauliodus* emit light when the fishes are placed in a weak solution of adrenalin in seawater. Injection or topical application of adrenalin solution was also effective in stimulating luminescence. Injection of adrenalin elicited luminescence from the ball-shaped bodies of *Stomias* without noticeable delay near the point of injection; then the luminescence spread in the course of several seconds to the rest of the ball-shaped bodies on the dorsal and ventral margins of the fish and on the fins. Tactile stimulation following injection of adrenalin

spread the glow more rapidly. Topical application of adrenalin elicited luminescence rapidly from the ball-shaped bodies around the site of stimulation. The glow spread gradually to other parts of the body. The *Stomias* I have observed usually luminesced for several seconds to about a minute. Repeated stimulation with adrenalin sometimes evoked weaker subsequent responses. I found on one occasion that a few of the luminescing ball-shaped bodies of *Stomias* continued to glow for a few seconds after being removed from the fish. The luminescence I have seen in *Idiacanthus* lasted only a few seconds. In rare cases, merely touching *Stomias* or *Idiacanthus* caused them to light up brightly.

Adrenalin stimulates not only the small unpigmented luminous organs but also the large body photophores and the postorbital photophores.

No emission spectra have been recorded for the luminescence of these three stomiatoid fishes. To my dark-adapted eyes, however, the color of the luminescence of *Stomias* was usually yellowish, although one especially bright-glowing specimen looked distinctly bluish. In *Idiacanthus*, too, the luminescence has sometimes appeared yellowish, at other times blue-green.

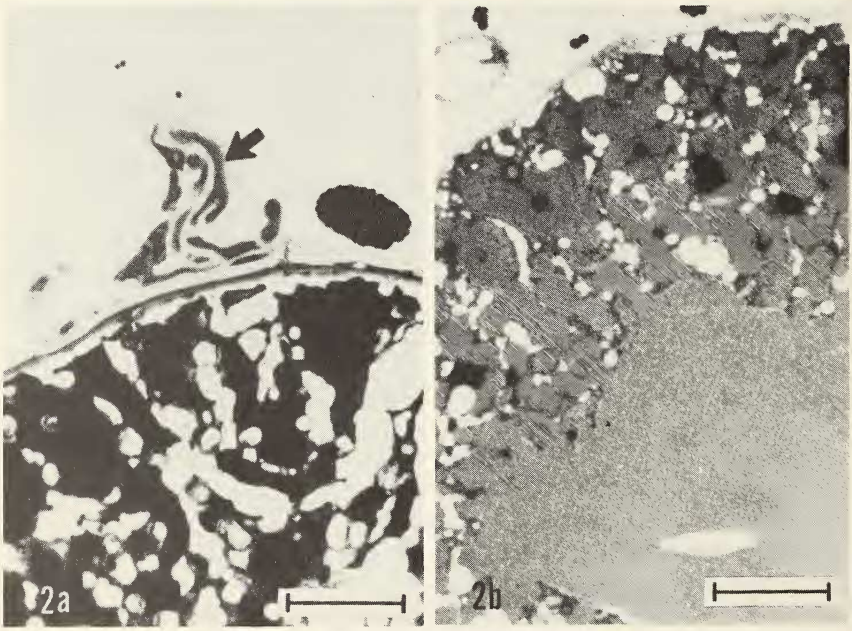


FIGURE 2a. Section of one of the minute ball-shaped bodies of *Stomias atriventer* where a nerve (arrow) approaches it.

FIGURE 2b. Section of one of the minute ball-shaped bodies of *Chauliodus macouni*. Specimens fixed with glutaraldehyde and osmium, embedded in Epon, and stained with toluidine blue. The scale for both figures equals 20 microns.

HISTOLOGICAL STRUCTURE

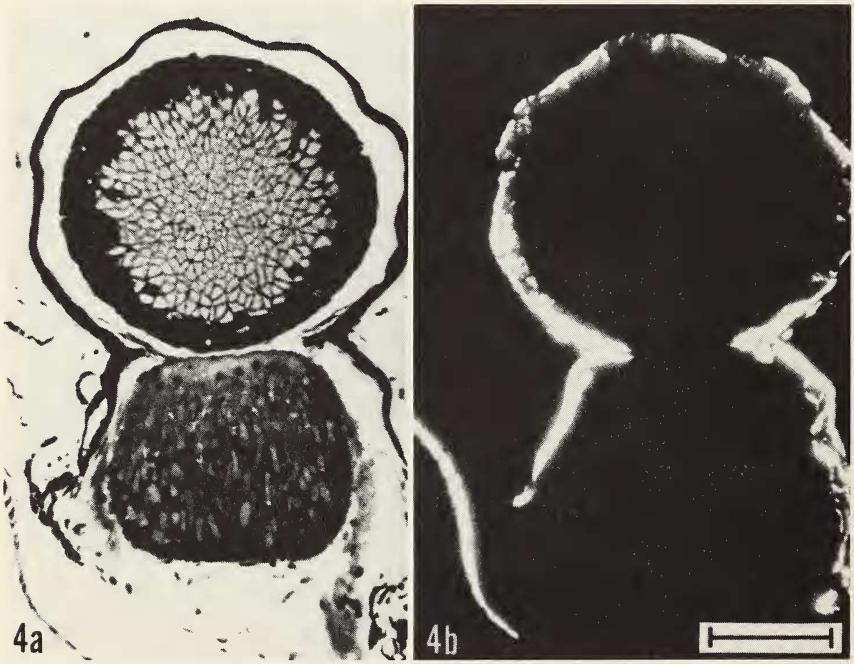
The suggestion that the ball-shaped bodies and masses of tissue around the fins are luminescent was put forward many years ago by several classical histologists, especially Brauer (1908), who noted their similarity to tissue in the photophores, barbels, and subocular light organs of these fishes. Microscopically the luminous bodies of *Stomias* and *Idiacanthus* appear similar: they are solid balls of secretory cells in which the secretory product is usually intracellular. A thin layer of a second kind of cell—the "bindegewebige Hülle" of Brauer—encloses the mass of secretory cells. The outermost layer of each ball consists of a well-developed basal lamina. Nerves terminate at the surfaces of these bodies but do not penetrate them (Fig. 2a). The spherical luminous bodies of *Chauliodus* elaborate their secretory product in a peripheral layer of cells, after which it accumulates in a central lumen (Fig. 2b). When fresh undamaged specimens of *Stomias* or *Chauliodus* are viewed with a dissecting microscope, the nerves appear as white threads running through the gelatinous sheath, their branches going to the luminous bodies. Figure 3 shows a cross section of such a nerve fiber from the gelatinous sheath of *Chauliodus* which contains several myelinated axons of varying diameter.

The gelatinous sheath of *Chauliodus* and *Stomias* is really a highly hy-

FIGURE 3. Cross section of a nerve fiber in the mucous sheath of *Chauliodus macouni*, a specimen 230 mm SL. The myelin sheaths of the axons appear black. Fixed with glutaraldehyde and osmium, embedded in Epon, and stained with toluidine blue. The scale equals 20 microns.

drated part of the dermis, as Brauer (1908) realized. In addition to the spherical or ovoid bodies, it contains nerves, blood vessels, a sparse network of fibroblasts and collagen, and mucoid substance. In life the mucous sheath is perfectly transparent. It is well developed along the dorsal and ventral margins of the body. However, it is very thin or absent on the lateral surfaces of the body. A thin epithelium lies over the mucous sheath and the other exposed parts of the body.

The secretory nature of these luminescent bodies and their pink appearance in life are properties that they share with the large, serially arranged photophores on the ventral part of the body. The serial ventral photophores, however, lack innervation according to Brauer's (1908) study of *Idiacanthus fasciola, Chauliodus sloani* and *C. pammelas,* and *Stomias valdiviae (= S. affinis).* Bassot (1966) found no innervation in his study of the serial ventral photophores of a species of *Chauliodus* with the light and electron microscope. The serial ventral photophores are also considerably more elaborate in structure (Fig. 4), being composed of pigment sheath, reflector, and at least two kinds of secretory cells (Bassot, 1966). The position of the photophores on the



FIGURES 4a and 4b. Transverse section of one of the large body photophores of *Chauliodus macouni,* viewed with normal brightfield illumination and between crossed polarizers, respectively. The crystals of the reflector are strongly birefringent. Fixed with glutaraldehyde, embedded in glycol methacrylate, stained with acid fuchsin and toluidine blue. The scale equals 100 microns.

body and their association with pigment sheath and reflector ensure that their luminescence is ventrally directed.

The ventral position of the large serial photophores and the ventral direction of their luminescence have been explained in terms of the hypothesis that ventral luminescence in midwater animals serves to camouflage them, when they are viewed from below by potential predators against the dimly lit upper layers of water (Fraser, 1962; Jerzmánska, 1960; Clarke, 1963; McAllister, 1967; Hastings, 1971). Camouflage does not seem a likely function, however, for the naked luminous tissue on the fins and on the dorsal and ventral margins of these fishes. This kind of luminescent organ seems to do just the opposite: to render the outline of the fishes visible (Fig. 5). Luminescent silhouetting may aid them in mating, spacing themselves out as they hunt, maintaining conspecific aggregations, warning potential predators of their own formidable size, or perhaps allowing them to escape from predators by temporarily blinding them. These functions, however, remain speculative.

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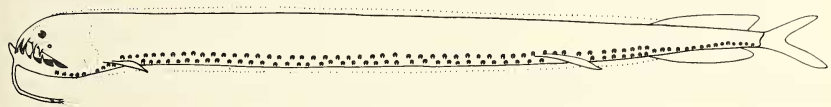

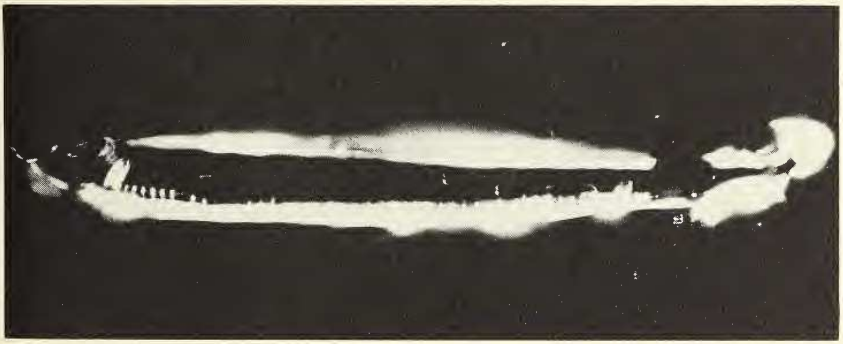

FIGURE 5. Drawing of the deep-sea fish *Stomias atriventer* Garman, and photograph of a specimen taken by the light from its own bioluminescence following stimulation with adrenalin. The specimen was 192 mm SL.

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